Eureka to Howardsville – August 1998

The California Gulch study reach ended just downstream from Animas Forks (fig. 1). There was a substantial part of the Upper Animas subbasin from that point to just upstream from Eureka Gulch that was not covered by a mass-loading study. Load information for the upstream end of the Eureka to Howardsville tracer study gives a net account of the loading in this unstudied reach, but does not include detail about any sites in the reach.

A main objective of the tracer study from Eureka to Howardsville was to quantify the flow and metal loading through a braided reach between Eureka Gulch and Minnie Gulch (fig. 61). This section of the study reach could act as a source or a sink for metals in the Upper Animas River, and quantification with a mass-loading study would help to define how the braids affect loads downstream. Details of the mass-loading study for this reach have been published by Paschke and others (in press). The following discussion summarizes findings of that report.

Study Area and Experimental Design

The mass-loading study for Eureka to Howardsville, called the Eureka study reach in this report, covered a 6,128 m section of the Upper Animas subbasin, starting upstream from Eureka Gulch, and continuing to a point just downstream from the gaging station near Howardsville (figs. 1 and 66). This distance was divided into 32 stream segments, 15 of which bracketed 18 sampled inflows along the study reach. The largest of these inflows were Eureka Gulch (EI-347), Minnie Gulch (EI-2420), Maggie Gulch (EI-3450), and Cunningham Gulch (6558), along with several seeps and springs. Site designations for stream and inflow samples are listed with other identifying information in table 22.

Figure 66 near here.

Figure 66. Location of synoptic sampling sites and important features, Upper Animas River near Eureka, Colorado, August 1998.

Table 23. Synoptic sampling sites, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

Site Disignation	Distance	Source	Site Name	CFS	pH	Cl, diss	SO4, diss
ES-0000	0	Stream	Upstream from injection site	12.58	7.35	0.20	54.70
ES-0080	80	Stream	First site below injection	12.58	7.34	14.20	55.15
ES-0282	282	Stream	UAEH1 site. Up from Eureka Gulch.	12.58	7.41	11.42	55.24
EI-0347	347	Inflow	Eureka Gulch (A21)	5.79	7.38	0.27	90.73
ES-0586	586	Stream	Down from Eureka Gulch	18.37	7.21	7.59	66.38
ES-0786	786	Stream	Near RB talus slope	18.37	7.28	7.59	66.53
ES-0906	906	Stream	Up from first braids	18.55	7.44	7.58	66.01
ES-1061	1061	Stream	Upper braided reach	18.55	7.36	7.50	65.48
ES-1411	1411	Stream	Left braid nr Forest Queen	18.55	7.27	7.61	66.45
ES-1618A	1618	Stream	Braid A	18.74	6.98	7.39	66.07
ES-1618B	1618	Stream	Braid B	18.74	7.45	7.39	66.07
ES-1618C	1618	Stream	Braid C	18.74	7.27	7.39	66.07
ES-1618D	1618	Stream	Braid D	18.74	7.17	7.39	66.07
ES-1918	1918	Stream	Left braid Down from Forest Queen	19.30	6.59	7.09	65.91
EI-1940	1940	Inflow	RB inflow resembles stream water	8.49	7.29	6.08	65.42
ES-2030	2030	Stream	Up from Forest Queen inflow	27.80	7.13	5.00	61.33
EI-2090	2090	Inflow	Inflow from Forest Queen Mine	0.60	7.22	1.40	63.56
ES-2240	2240	Stream	UAEH2 site. Up from Minnie Gulch.	28.35	6.78	4.45	62.16
ES-2420	2420	Stream	Up from Minnie Gulch	28.35	6.65	4.51	61.78
EI-2465	2465	Inflow	Minnie Gulch (A22)	3.97	7.93	0.21	60.96
ES-2620A	2620	Stream	Down from Minnie Gulch A	32.31	7.03	3.93	61.87
ES-2620B	2620	Stream	Down from Minnie Gulch B	32.31	7.16	3.93	61.87
ES-2860	2860	Stream	Near braided area	32.96	7.34	4.00	62.20
ES-3150	3150	Stream	Up from inflow nr Kitty Mack	34.28	7.30	3.72	61.66
EI-3165	3165	Inflow	Up from Otto Gulch fan	4.11	6.32	0.24	127.97
ES-3400	3400	Stream	Down from braids nr Kitty Mack	38.39	7.05	3.33	64.02
EI-3405	3405	Inflow	Drains hillslope or aluvium	4.22	7.11	0.65	58.91
ES-3435	3435	Stream	Up from Maggie Gulch	42.62	6.88	2.94	63.52
EI-3450	3450	Inflow	Maggie Gulch (A23)	2.56	7.95	0.19	43.77
ES-3665	3665	Stream	Down from Maggie Gulch	45.17	7.22	2.77	62.60
ES-3905	3905	Stream	Up from braided reach	45.63	7.64	3.11	62.20
EI-3954	3954	Inflow	Drains large area of willows.	2.28	6.51	0.27	94.94
ES-4164	4164	Stream	Near beaver ponds on LB.	47.91	6.89	2.64	63.36
EI-4189	4189	Inflow	Inflow from beaver ponds.	2.87	6.99	0.36	77.10
ES-4430	4430	Stream	Down from beaver ponds on LB	50.78	7.05	2.51	65.27
ES-4670	4670	Stream	Downstream from braids.	53.32	6.79	2.33	67.91
ES-4970	4970	Stream	Along smooth reach of stream	54.92	7.04	2.33	69.30
ES-5190	5190	Stream	Upstream from beaver inflow	55.47	7.00	2.30	68.94
EI-5210	5210	Inflow	Drains beaver pond	0.28	7.74	0.28	85.81
EI-5407	5407	Inflow	Drains ponds.	0.28	6.83	1.58	58.91
ES-5467	5467	Stream	UAEH3 stie. Last year's injection site.	56.02	7.37	2.30	70.60
EI-5648	5648	Inflow	Drains upstream from tailings piles (A24)	0.56	7.30	2.52	73.76
ES-6038	6038	Stream	Along tailings piles. Last AMIN1.	56.58	7.14	2.26	70.73
EI-6438	6438	Inflow	Inflow from Howardsville Mill	0.57	5.68	5.17	306.84
ES-6528	6528	Stream	Down from Howardsville Mill	57.15	7.33	2.26	73.98
EI-6558	6558	Inflow	Cunningham Gulch. (A27)	11.43	7.60	0.28	54.09
ES-6618	6618	Stream	Down from Cunningham Gulch	68.58	6.98	2.08	70.68
EI-6633	6633	Inflow	Hematite Gulch. (A25)	3.43	7.81	0.25	69.33
ES-6753	6753	Stream	Down from Hematite Gulch (A26)	72.01	7.09	1.80	70.41
ES-6993	6993	Stream	UAEH4 site. At Howardsville gage	72.73	6.86	1.76	70.42
EI-7008	7008	Inflow	Drains LB adit up hill	0.01	7.09	0.30	265.71
EI-7013	7013	Inflow	Drains old mill site	0.13	7.25	3.79	46.59
EI-7063	7063	Inflow	Also drains old mill?	0.17	6.90	4.79	108.07
ES-7250	7250	Stream	Down from clean/dirty inflows	72.92	7.13	1.84	70.96

Abandoned mines and prospects exist along the study reach; the discharge from the Pride of the West Mill and tailings area near Howardsville (EI-6438) was one of the most visually significant for its iron staining in the stream (see Martin and others, Chapter 4G this volume). In general, the rocks on both sides of the canyon have propylitic alteration, but there also are areas of quartz-sericite-pyrite alteration (Bove and others, this volume). Stream elevation ranged from approximately 9,800 ft at the injection site to 9,640 ft downstream from Cunningham Gulch. Geology of the basin is described in Yager and Bove (this volume) and Bove and others (this volume).

Discharge

Sodium chloride was used as the tracer for this study reach. The injectate solution had a chloride concentration of 101,100 mg/L, and was injected at a rate of 1.784 L/min, starting 1002 hours on 12 August 1998, and ran continuously until 1930 on 14 August 1998 (Paschke and others, in press). Background concentrations of chloride were low in comparison to the injected concentrations (fig. 67). Chloride decreased systematically downstream from the injection, indicating those stream segments receiving inflow. Discharge increased by 60.3 ft^3/s along the study reach, and stream segments that contained sampled inflows accounted for 85 percent of this increase. Those segments that had no sampled inflows contributed 15 percent of the increase. This would be the minimum contribution for dispersed, subsurface inflow along the study reach.

Figure 67 near here.

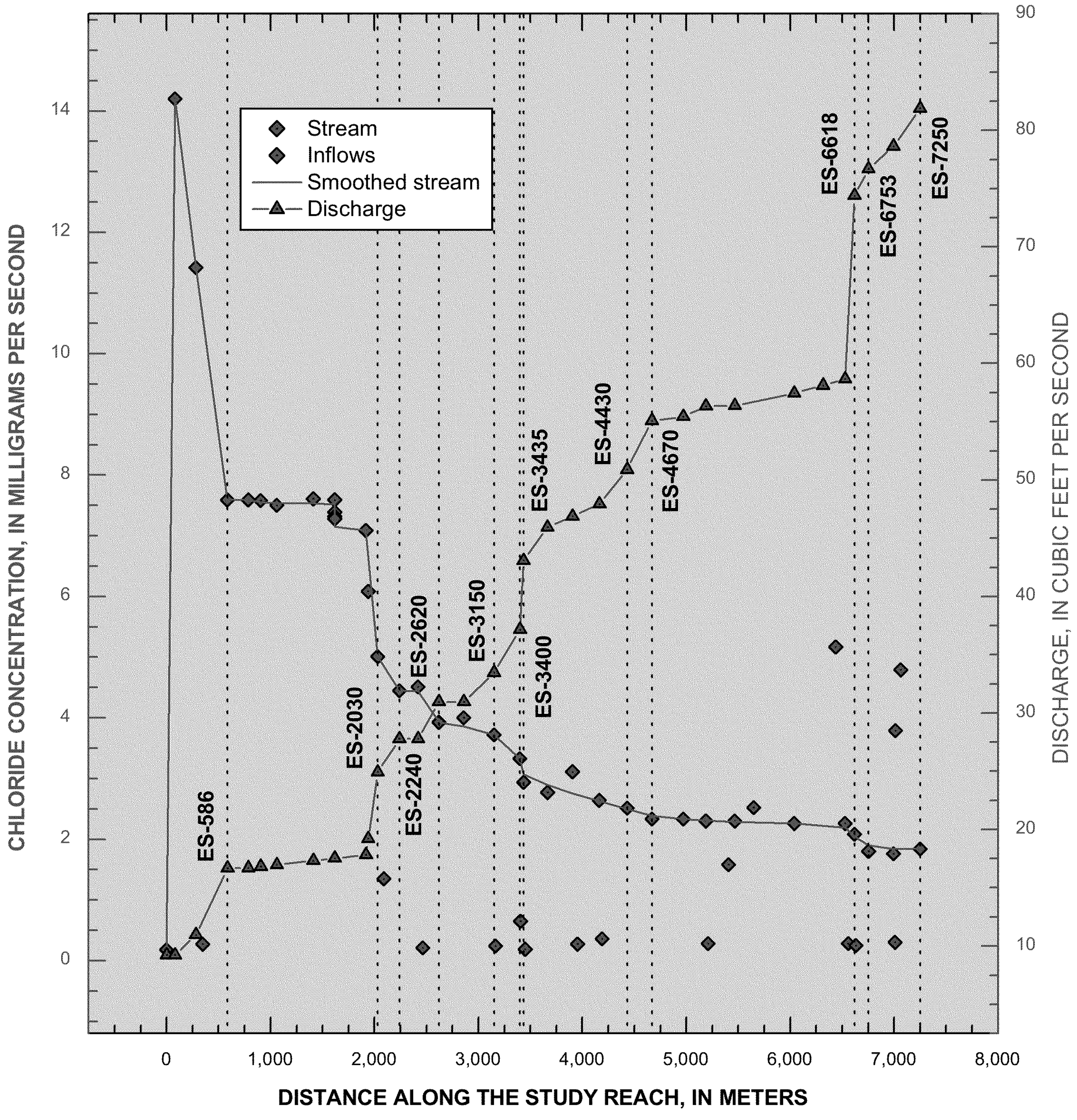

Figure 62. Variation of chloride concentration and calculated discharge, Upper Animas River from Eureka to Howardsville, Coloardo, August 1998.

Cunningham Gulch (segment ES-6618) was the largest tributary inflow, accounting for 11.4 ft^3/s, or 19 percent of the flow. The change in flow through the braided reach of stream (fig. 61) is accounted for at segment ES-2030, downstream from where the braids come back together (fig. 61). The increase at that point was 8.5 ft^3/s, or 14 percent of the increase in flow. Eureka Gulch (ES-586) contributed 5.8 ft^3/s or about 10 percent of the increase. Maggie Gulch (ES-3435), the area near the Kitty Mack tailings (ES-3400), Minnie Gulch (ES-2240), and Hematite Gulch (ES-6753) each contributed greater than 5 percent of the flow.

Characterization of Synoptic Samples

Along the study reach, pH ranged from about 6.6 to 7.6; but there was no systematic spatial trend of pH (fig. 68a). Only the inflow from the tailings near Howardsville (EI-6438) had a pH value less than 6.0. Throughout the study reach, the dominant major ions were calcium and sulfate; alkalinity was about half of the sulfate concentration (fig. 68b). Like values of pH, there was not much variation in these major ion concentrations.

Figure 68 near here.

Despite the consistent major-ion concentrations along the study reach, concentrations of metals did vary. Aluminum, copper, manganese, strontium, and zinc were elevated (fig. 69). Lead and nickel concentrations generally were less than detection. Manganese concentrations ranged up to 0.78 mg/L and had a median of 0.30 mg/L. Median concentration of zinc also was 0.30 mg/L (fig. 69). Colloidal concentrations of aluminum and iron were greater than dissolved concentrations, which was consistent with the relatively high pH of the study reach (figs. 68a and 69). The median concentration of colloidal iron was 0.049 mg/L; while the median dissolved concentration was less than detection, indicating the dominance of the colloidal phase. Colloidal concentrations of copper and zinc also were measurable, but generally less than dissolved concentrations. The median concentration of colloidal copper was less than detection, but of colloidal zinc was 0.011 mg/L.

Figure 69 near here.

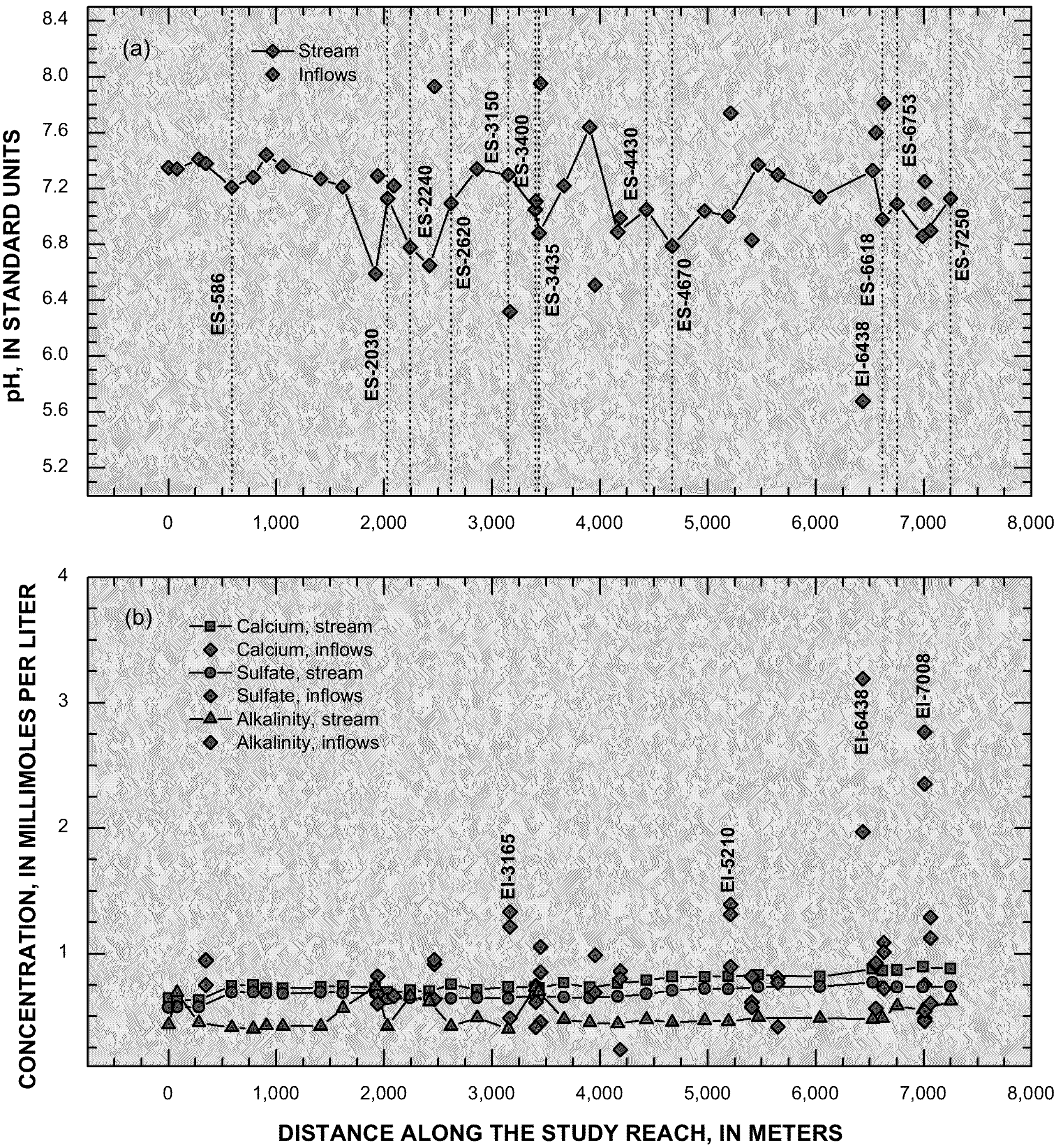

Figure 68. Variation of (a) pH and (b) calcium, sulfate, and alkalinty with distance along the study reach, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

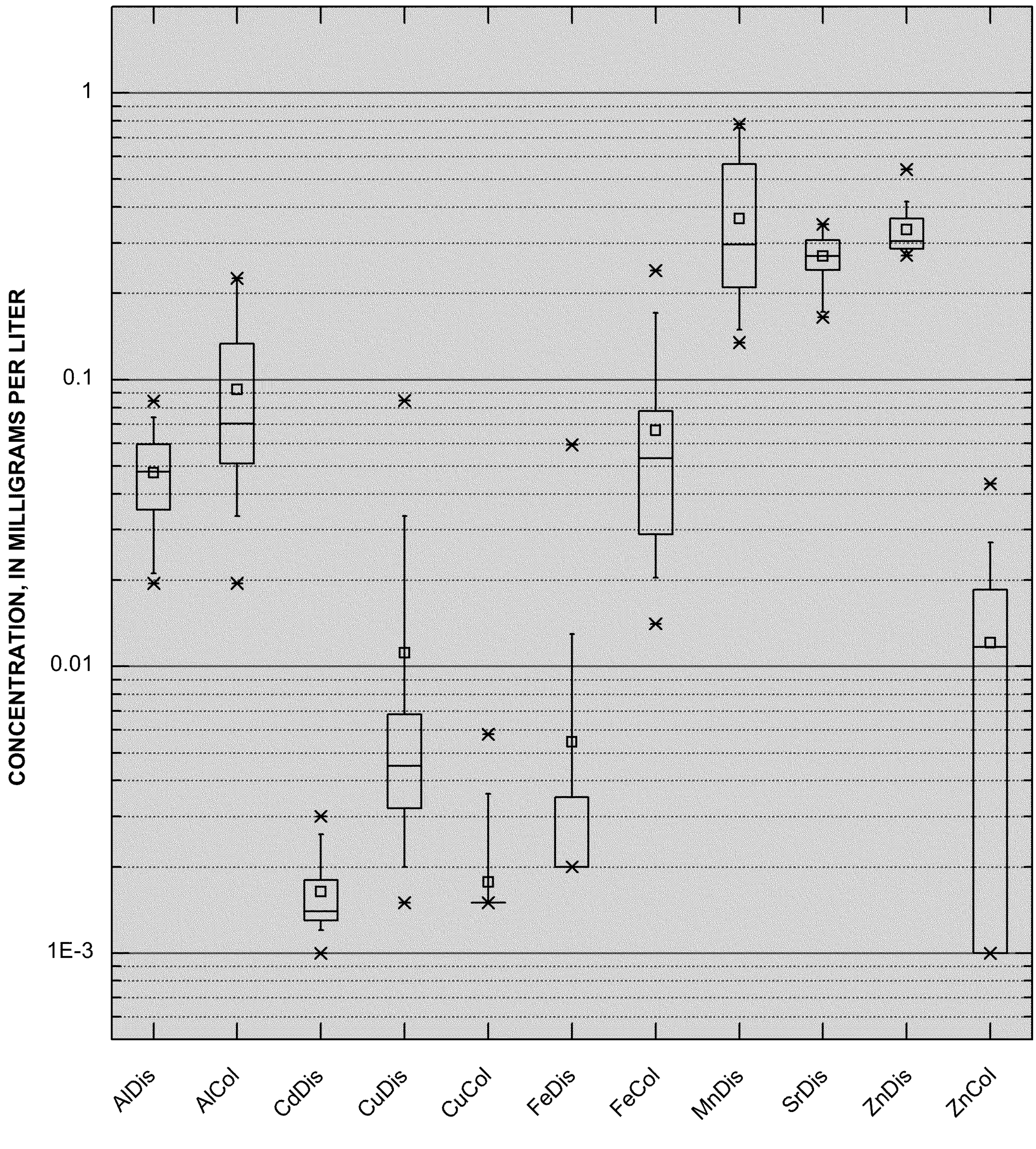

Figure 69. Box plots showing distribution of dissolved and colloidal concentrations of metals in synoptic stream stamples, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

Colloidal concentrations of aluminum and copper mostly occurred at the beginning of the study reach, and were less predominant after the braided reach of the stream (downstream from ES-2030, figs. 70 and 71). The highest inflow concentration of aluminum occurred in the discharge near Howardsville (EI-6438). The last two sampled inflows, EI-7013 and EI-7063, had the highest inflow concentrations of copper. Unlike any of the other metals, copper concentrations, for both the 0.45-μm filtrate and the total-recoverable concentrations were highest at ES-80, rather than at EW-0, at the beginning of the study reach. This could be due to a dispersed, subsurface inflow with high copper concentration in the segment ES-80, which is near the old Eureka Mill.

Figures 70 and 71 near here.

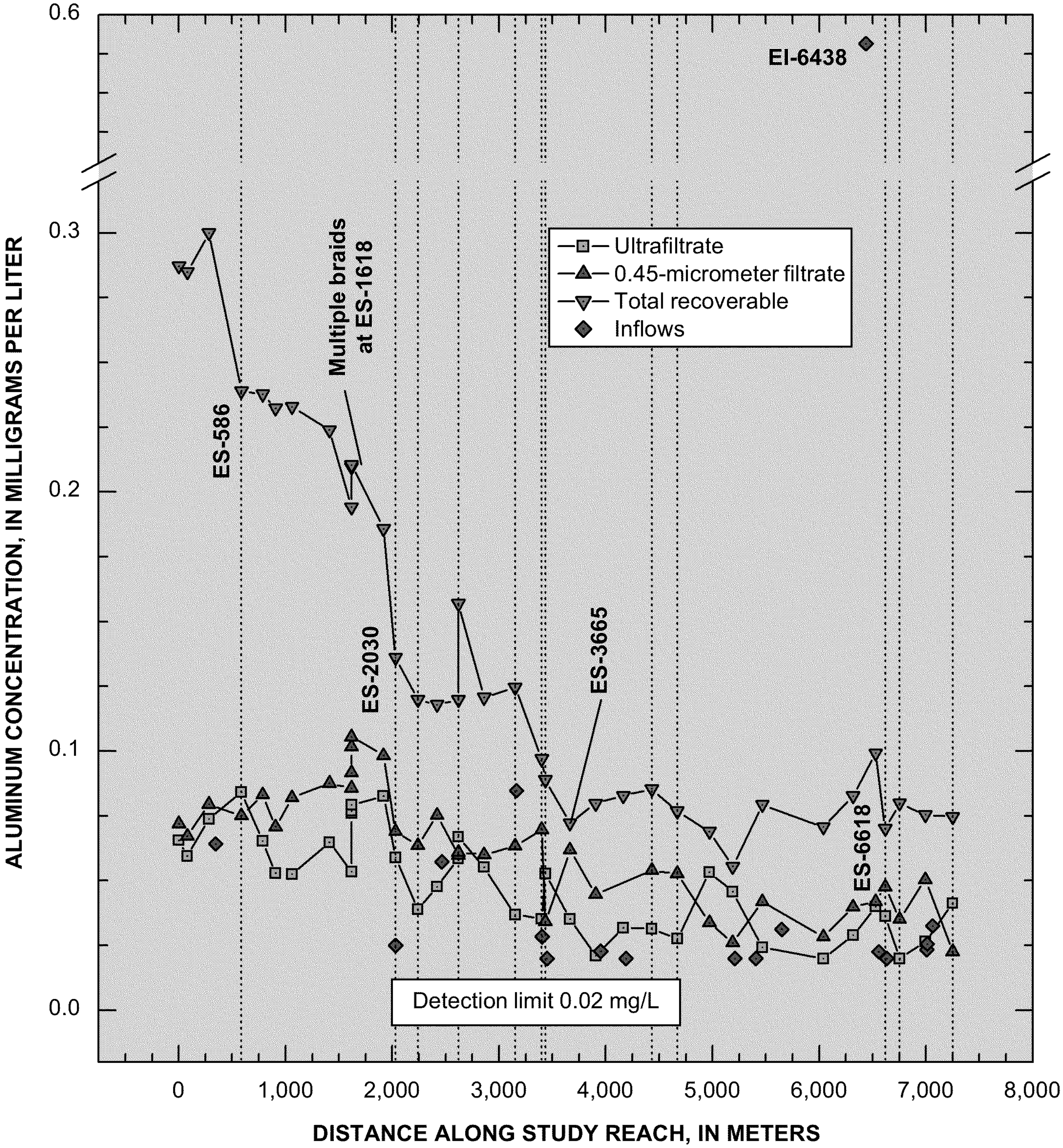

Figure 70. Variation of aluminum concentration in ultrafiltrate, 0.45-μ m filtrate, and total-recoverable samples with distance along the study reach, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

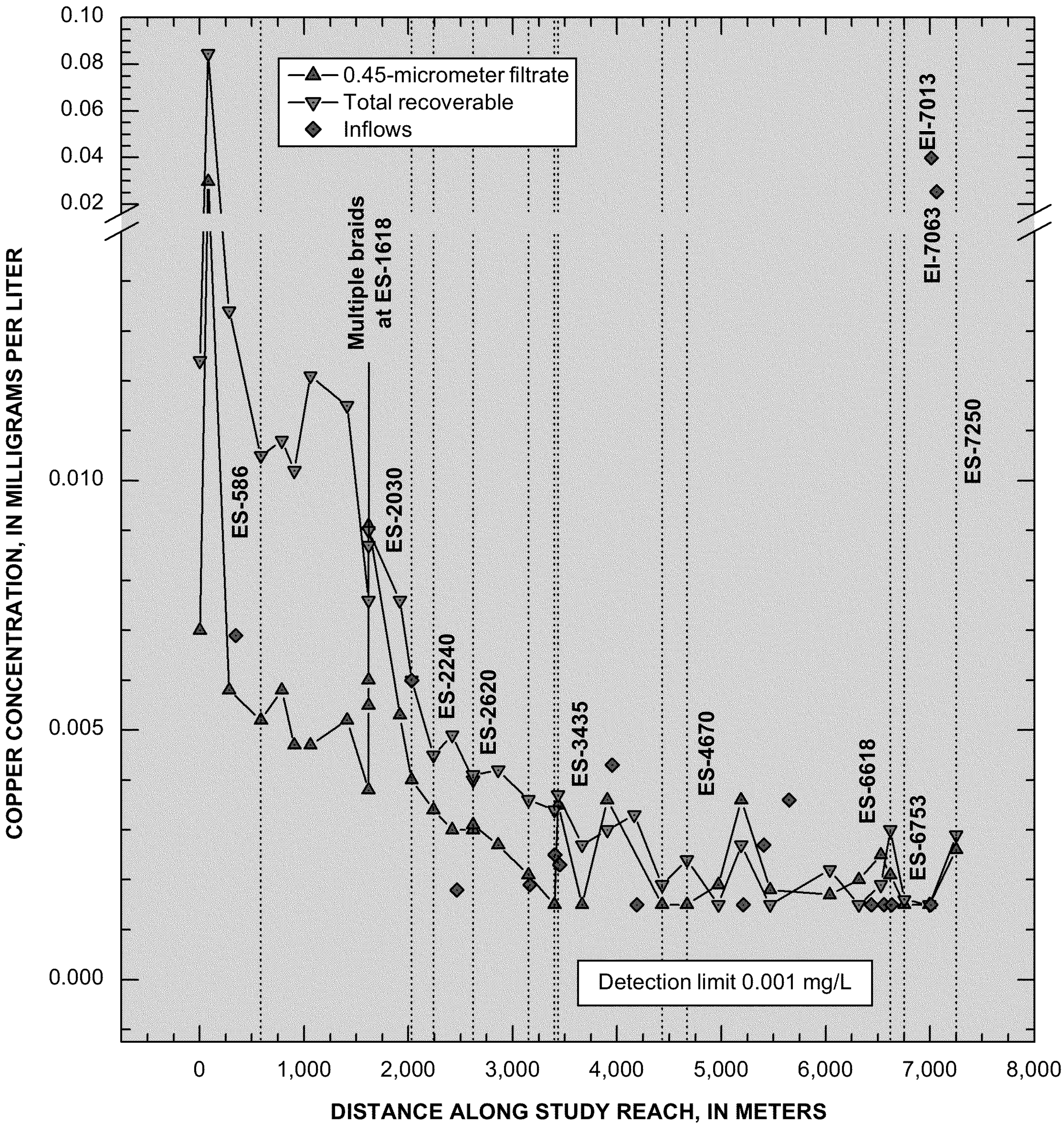

Figure 71. Variation of copper concentration in 0.45-μ m filtrate and total-recoverable samples with distance along the study reach, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

At the beginning of the study reach, colloidal iron concentrations were relatively high, comparable to colloidal aluminum and copper (fig. 72). However, colloidal iron concentrations were much higher downstream from the inflow at EI-6438, which had visible iron staining, along the left bank all the way to Cunningham Gulch (EI-6558). Note that the total-recoverable and 0.45-μm filtered concentrations increased substantially with this inflow, but the increase of ultrafiltrate iron was much lower. This indicates the effectiveness of the various filter sizes to distinguish dissolved iron in this reach. There could have been some colloidal material in the ultrafiltrate, however, it was much more effective in separating the dissolved and colloidal iron (Kimball and others, 1995).

Figure 72 near here.

The highest instream concentration of zinc occurred at the beginning of the study reach (fig. 73). Through the braided reach, zinc concentration decreased, but then increased downstream from the Forest Queen Mine, downstream from ES-2030. Downstream from Minnie Gulch zinc concentrations remained nearly constant at about 0.3 mg/L until ES-6528, downstream from the inflow draining mill tailings near Howardsville. Several of the ultrafiltrate zinc concentrations were greater than the total-recoverable concentrations, so there could have been some contamination. Thus, the ultrafiltrate concentration is not shown in figure 73.

Figure 73 near here.

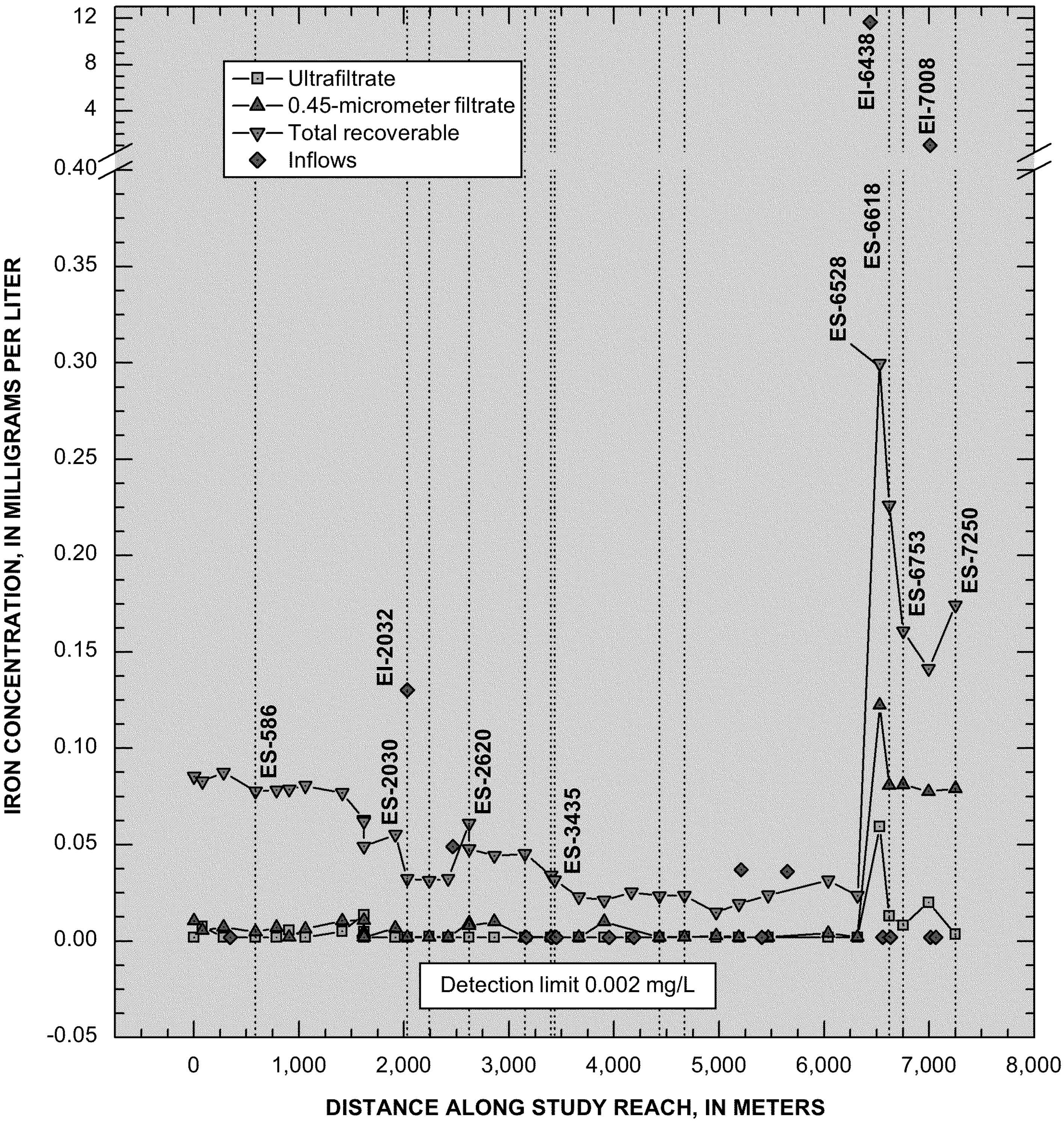

Figure 72. Variation of iron concentration in ultrafiltrate, 0.45-micrometer filtrate, and total-recoverable samples with distance along the study reach, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

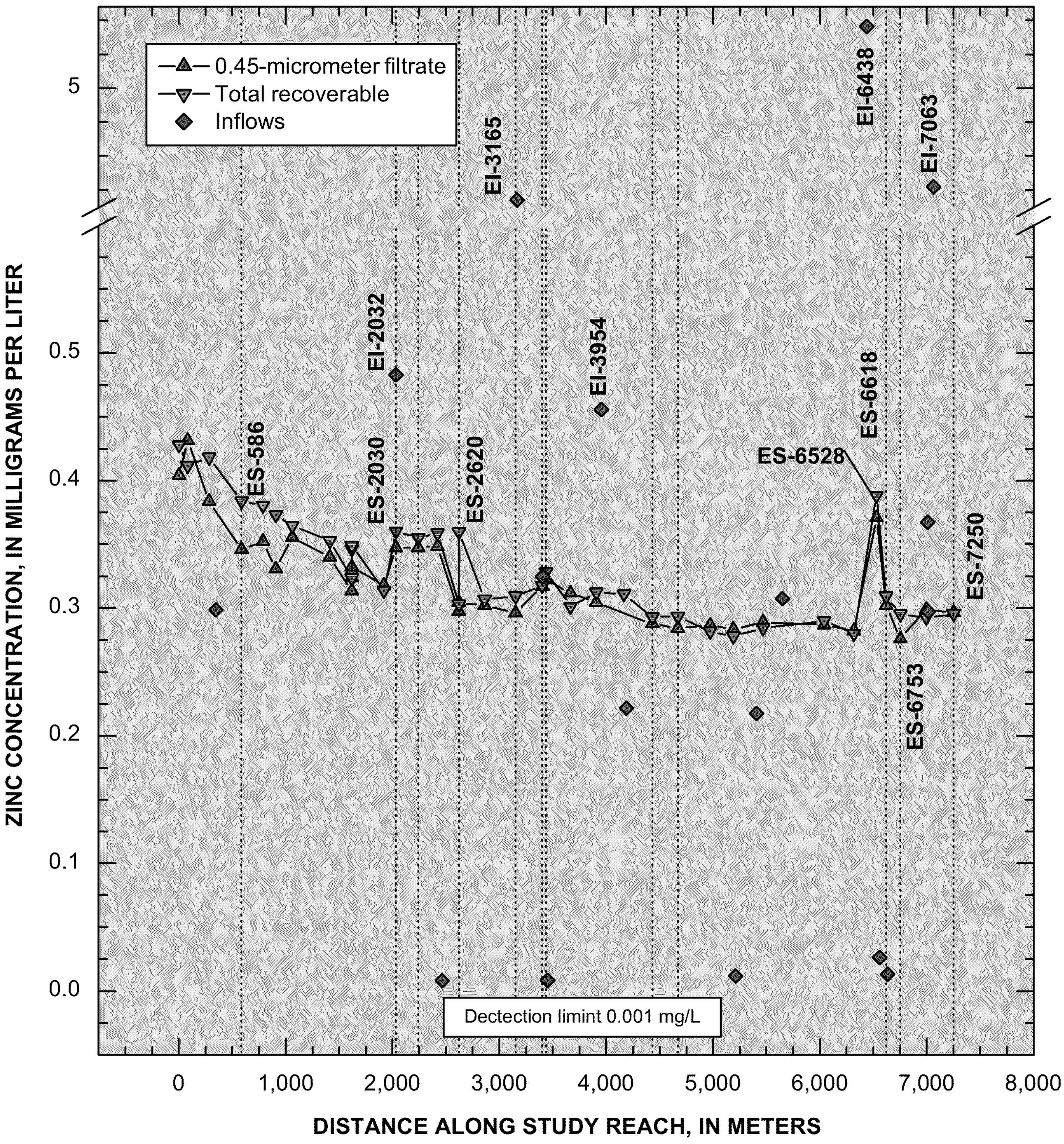

Figure 73. Variation of zinc concentration in 0.45-micrometer filtrate and total-recoverable samples with distance along the study reach, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

Variations in concentration, especially the changes that occur as water moves through the braided reach between Eureka and Howardsville, help to classify stream and inflow samples by means of PCA. Two groups of stream samples and four groups of inflow samples were identified. The biplot indicates the covariance of the solutes; the covariance results from the chemical and physical process affecting the transport and transformation of metals from various sources in the watershed (fig. 74). The median concentration of samples in each group, broken down between stream and inflow samples, is listed in table 23. Stream samples near the top of the biplot have the highest concentrations; these are the most upstream sites, upstream from Eureka Gulch (ES-0 and ES-280). Vectors for copper and aluminum are grouped together because of the decrease in colloidal concentrations through the braided reach; group 1 stream samples had lower concentrations than group 2 stream samples. Metals, including manganese, zinc, cadmium, and iron are grouped with hydrogen ion, or acidity, and the changes among groups of stream samples represent the decreased concentrations of these metals downstream from the braided reach. Finally, sulfate, magnesium, calcium, and strontium are grouped because of bedrock weathering.

Figure 74 near here.

Groups of inflow samples plot around the stream samples and represent the compositional end members that result from water-rock interactions in the watershed. Note that most of the inflows in this study reach plot away from higher metal concentrations (indicated by the direction of the arrows). There was only one metal-rich inflow at EI-6438, the drainage from old tailings near Howardsville.

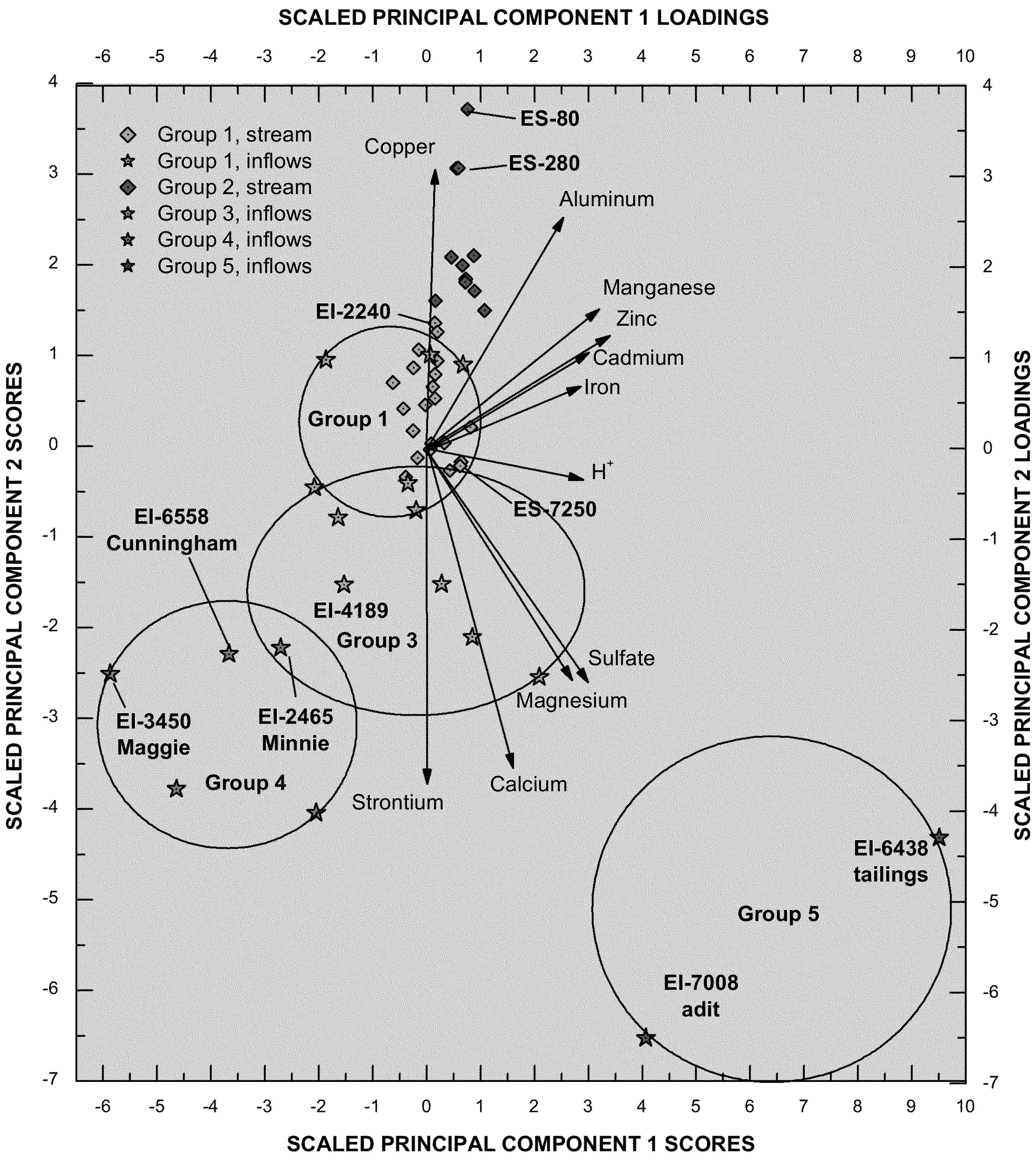

Figure 74. Biplot showing groups of inflows and stream sites, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

Table 24. Median concentrations of stream and inflow samples classified by PCA groups, Upper Animas River, Eureka to Howardsville, Colorado, August 1998.

Solute	Phase	Group 1 – Downstream from braided reach	Group 1 – Unaffected inflows	Group 2 – From Eureka through braided reach	Group 3 --	Group 4 --	Group 5 – Tailings discharge and adit drainage
		Stream	Inflows	Stream	Inflows	Inflows	Inflows
pH	Dis	7.07	7.27	7.28	6.90	7.81	6.39
Calcium	Dis	31.1	31.3	29.0	38.1	36.8	86.7
Magnesium	Dis	2.23	2.38	2.21	2.35	2.46	7.46
Sodium	Dis	2.90	2.67	5.42	1.67	2.35	3.78
Chloride	Dis	2.42	3.16	7.59	.359	.250	2.74
Sulfate	Dis	64.6	64.5	66.0	90.7	61.0	286
Alkalinity	Dis	24.3	27.1	22.4	28.7	50.7	23.1
Silica	Dis	5.71	6.80	4.58	8.32	6.06	17.8
Aluminum	Dis	.037	.028	.065	.028	.017	.282
	Col	.057		.166			
Cadmium	Dis	.001	.003	.002	.002	LD	.006
	Col	LD		LD			
Copper	Dis	.004	.007	.019	.003	.001	LD
	Col	LD		LD			
Iron	Dis	LD	.033	LD	LD	LD	6.47
	Col	.031		.074			
Manganese	Dis	.261	.226	.571	.073	.005	9.91
	Col	.004		.007			
Nickel	Dis	LD	LD	LD	LD	LD	LD
	Col	LD		LD			
Lead	Dis	LD	LD	LD	LD	LD	LD
	Col	LD		LD			
Strontium	Dis	.291	.292	.240	.367	.504	.700
	Col	.004		.003			
Zinc	Dis	.289	.395	.387	.325	.012	3.90
	Col	.011		.007			

Load Profiles

Load profiles indicate the nature of changes through the braided reach, whether the changes result from dilution or reaction. . A summary of load calculations for this study reach is listed in table 25.There were three general patterns among metal loading profiles along the study reach from Eureka to Howardsville, and these patterns indicate differences among sources and reactions affecting the different metals.

Aluminum (fig. 75) and copper (fig. 76) had similar loading profiles, which were characterized by a large metal load at the beginning of the study reach that decreased through the braided reach. Although there were other locations of aluminum and copper loading within the study reach, they were small in comparison to the loads at the beginning of the study reach. Even though the aluminum concentration decreased substantially along the braided reach (fig. 70), the loss of aluminum load was not as substantial; the decrease in aluminum concentration was mostly due to dilution. The decrease in copper concentration (fig. 71), on the other hand, was due to actual loss of copper load (fig. 76b) through reaction and not due to dilution.

Figures 75 and 76 near here.

Table 25. Summary of load calculations for upper Animas Gulch, Eureka to Howardsville, Colorado, August 1998.

[Al, aluminum; Cd, cadmium; Cu, copper; Fe, iron; Mn, manganese; Ni, nickel; Sr, strontium; Zn, zinc; SO4, sulfate; loads are in kilograms per day.]

SITEID	DIST	Al	Cd	Cu	Fe	Mn	Sr	Zn	SO4
UAEH0	0	8.83	0.080	0.735	2.63	24.0	5.32	14.4	1,680
UAEH80	80	-.068	.034	1.89	-.077	-.643	-.203	2.29	14.0
UAEH282	282	.464	-.012	-2.08	.142	.711	.188	-3.81	2.62
UAEH586	586	1.51	.038	-.073	.798	2.07	5.69	4.38	1,280
UAEH786	786	-.058	-.031	.463	.027	.247	.117	-.040	6.66
UAEH906	906	-.138	-.017	.594	.053	-.126	.111	1.81	6.51
UAEH1061	1061	.023	.050	-.980	.086	-.209	-.127	-2.47	-24.4
UAEH1411	1411	-.404	-.045	.998	-.168	.435	.195	2.27	44.1
UAEH1618	1618	-.780	.056	.306	-.828	-.001	-.093	-.253	12.9
UAEH1918	1918	-.609	-.028	-1.49	-.055	-1.57	-.169	-3.75	83.1
UAEH2030	2030	.484	.040	.110	-.396	1.22	5.03	9.68	1,060
UAEH2240	2240	-.948	-.059	.030	-.033	-2.27	.738	.135	139
UAEH2420	2420	-.132	-.007	-.159	.062	.111	-.215	.263	-26.3
UAEH2620	2620	2.76	.033	-.020	2.06	2.13	6.40	1.32	606
UAEH2860	2860	-1.21	.031	.018	-.732	-1.62	-1.39	-1.44	125
UAEH3150	3150	.716	-.035	-.037	.227	.408	1.63	1.18	155
UAEH3400	3400	-1.34	.128	.139	-.586	-1.37	2.07	3.88	842
UAEH3435	3435	.158	-.055	-.056	.082	-.270	4.41	5.38	609
UAEH3665	3665	-1.29	-.043	.100	-.752	.024	2.39	-1.92	296
UAEH3905	3905	.928	.080	.016	-.187	.244	.499	1.58	23.9
UAEH4164	4164	.797	.012	.119	.610	-.289	2.13	1.59	483
UAEH4430	4430	.905	.002	.025	-.058	-1.54	2.01	-.035	682
UAEH4670	4670	-.591	-.053	-.137	.184	-.546	3.69	1.87	750
UAEH4970	4970	-.760	.033	-.146	-1.10	-.293	1.41	.262	452
UAEH5190	5190	-1.72	-.079	.004	.630	-.483	1.34	.087	44.6
UAEH5467	5467	3.34	.111	.415	.643	-1.11	-.308	.359	321
UAEH6038	6038	-1.08	.072	-.380	1.10	-.029	.899	1.14	115
UAEH6528	6528	4.08	-.081	-.136	37.5	33.4	2.67	14.1	552
UAEH6618	6618	-2.11	-.034	.238	-3.92	-2.84	10.8	-2.35	1,510
UAEH6753	6753	2.31	.029	.677	-9.64	1.25	4.10	.095	546
UAEH6993	6993	-.660	.145	.883	-3.15	-.326	.276	5.14	125
UAEH7250	7250	-.089	.037	-1.55	5.93	.672	.523	-4.39	131
Cumulative instream load		27.3	1.01	7.76	52.7	66.9	64.7	73.2	12,700
Cumulative inflow load		13.3	.24	1.07	20.0	54.5	47.5	48.1	11,000
Percent		49	24	14	38	82	73	66	87
Unsampled inflow		14.0	.76	6.69	32.7	12.4	17.1	25.1	1,670
Percent		51	76	86	62	18	27	34	13
Attenuation		14.0	.58	7.24	21.6	15.5	2.5	20.5	70.7
Percent		51	58	93	41	23	4	28	< 1

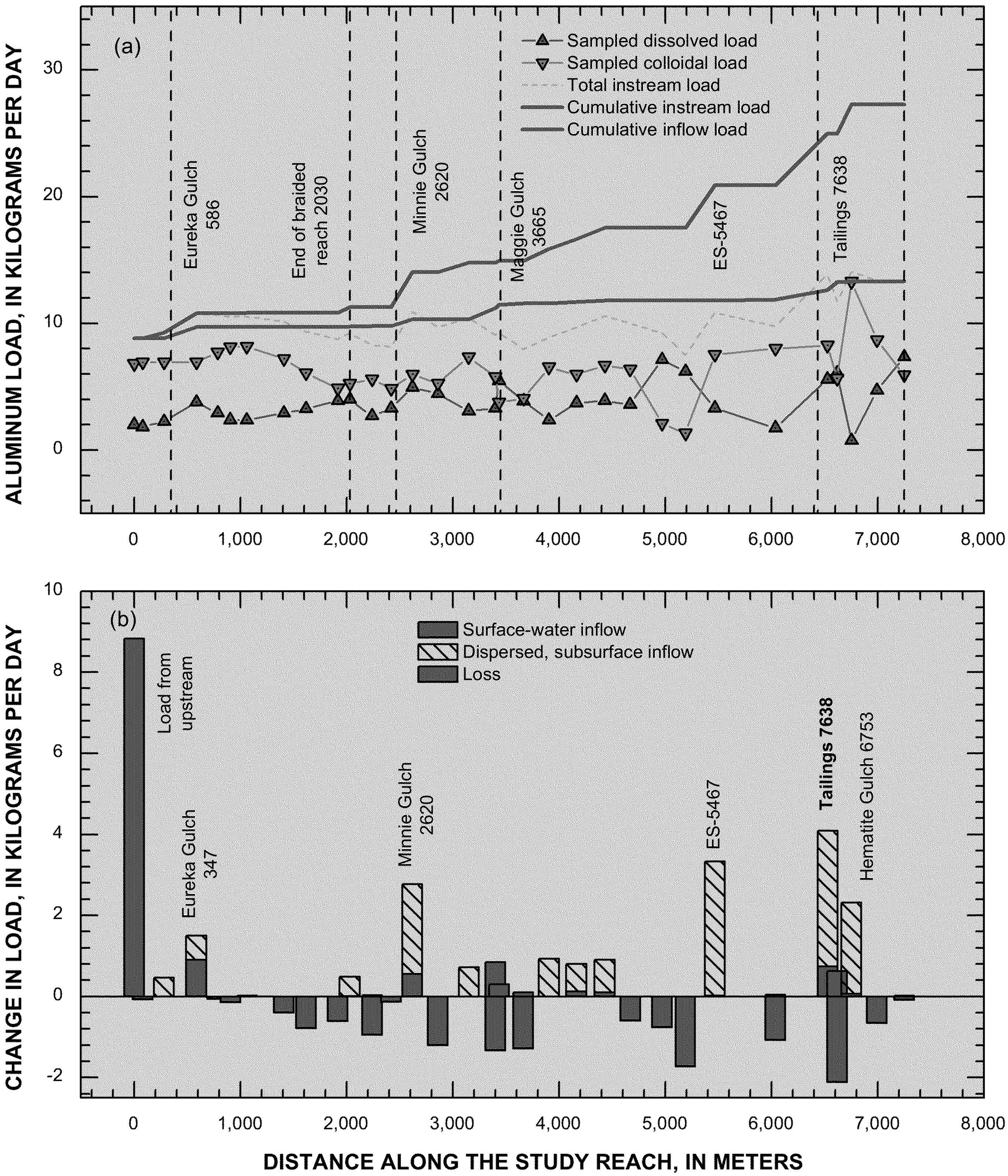

Figure 75. Variation of (a) aluminum load with distance and (b) change in load for individual stream segments, Eureka to Howardsville, Upper Animas River, Colorado, August 1998.

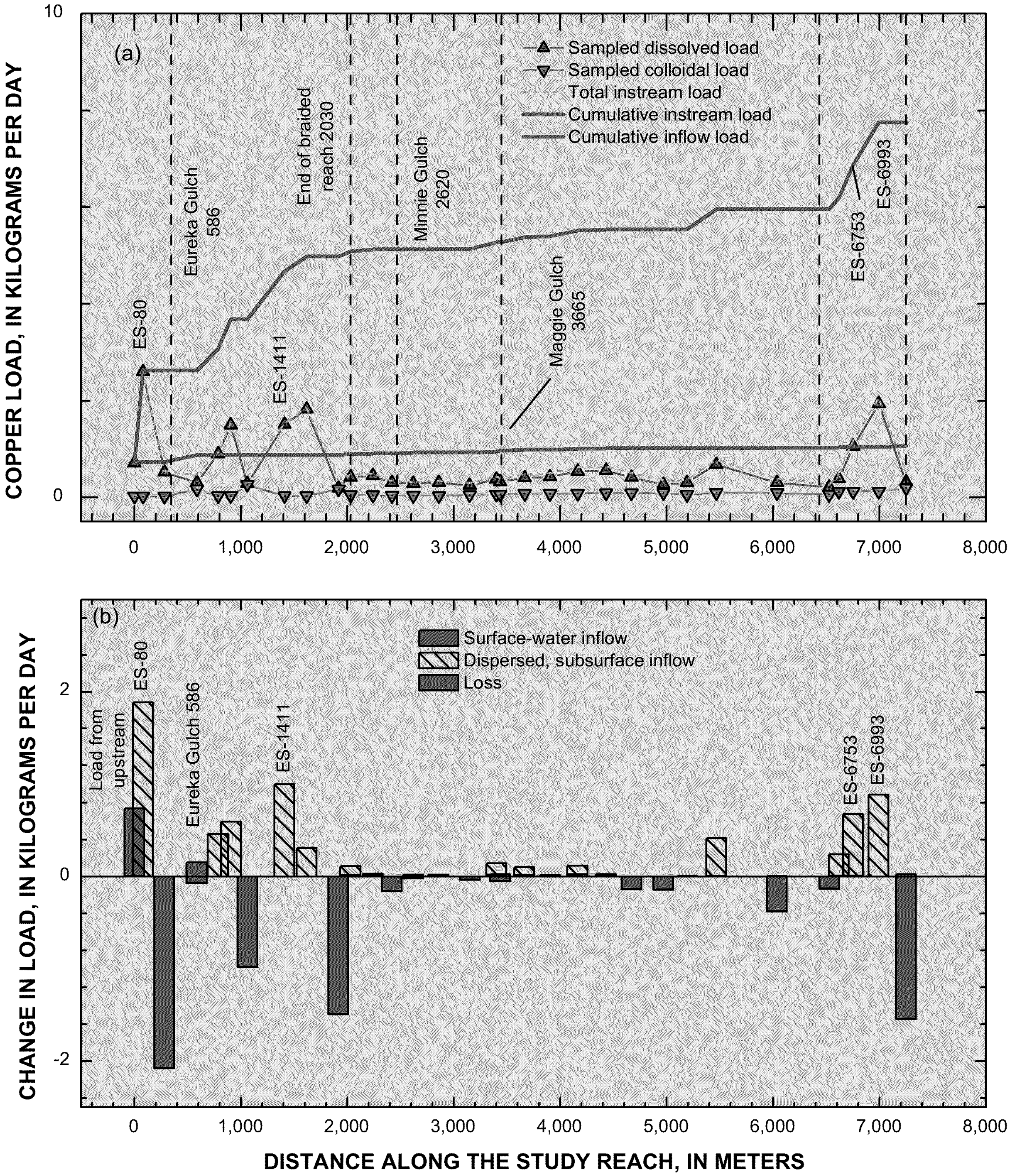

Figure 71. Variation of (a) copper load with distance along the study reach and (b) change in load for individual stream segments.

Although manganese (fig. 72) and zinc (fig. 73) loads are substantial at the beginning of the study reach, both these elements differ from aluminum and copper by having even greater loads contributed within the study reach. For manganese, the greatest load was contributed in the segment including the discharge from old tailings near Howardsville (ES-6528). Most of that load was due to surface-water inflow, but some of it was due to dispersed, subsurface inflow (fig. 72b). Zinc had substantial contributions from several segments along the study reach, but also from the drainage of old tailings near Howardsville (ES-6528). Loads were considerable from the segment at ES-2030, which was the end of the braided reach, and at ES-3400, which contained a large area of the old Kitty Mack tailings. The bar at ES-3400 in figure 73b indicates a surface-water inflow, because there was a right bank inflow that may have been from Otto Gulch on the right bank. The Kitty Mack tailings, however, were on the left bank, and so that inflow likely was subsurface inflow. Zinc also was contributed in the segment at the Howardsville gage, ES-6993, and this was a subsurface inflow.

Figures 72 and 73 near here.

Iron load (fig. 74) was similar to manganese and zinc because of the large load at ES-6528, draining the old tailings ponds near Howardsville. As in many other tracer-studies, the amount of iron inflows most likely is underestimated because iron is so reactive that a net reaction removes iron from the stream before the net accounting at the downstream site of the segment.

Figure 74 near here.

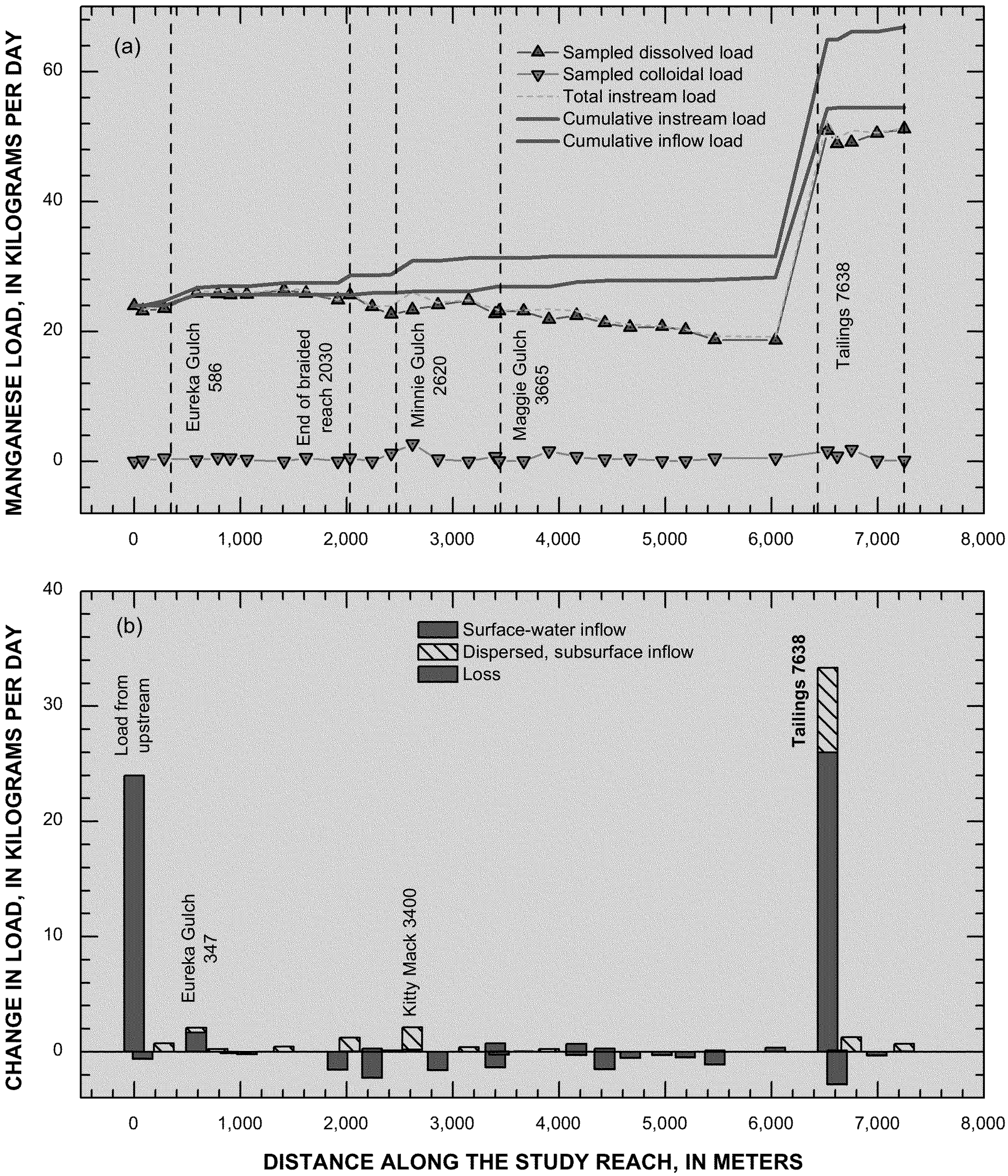

Figure 72. Variation of (a) manganese load with distance along the study reach and (b) change in load for individual stream segments.

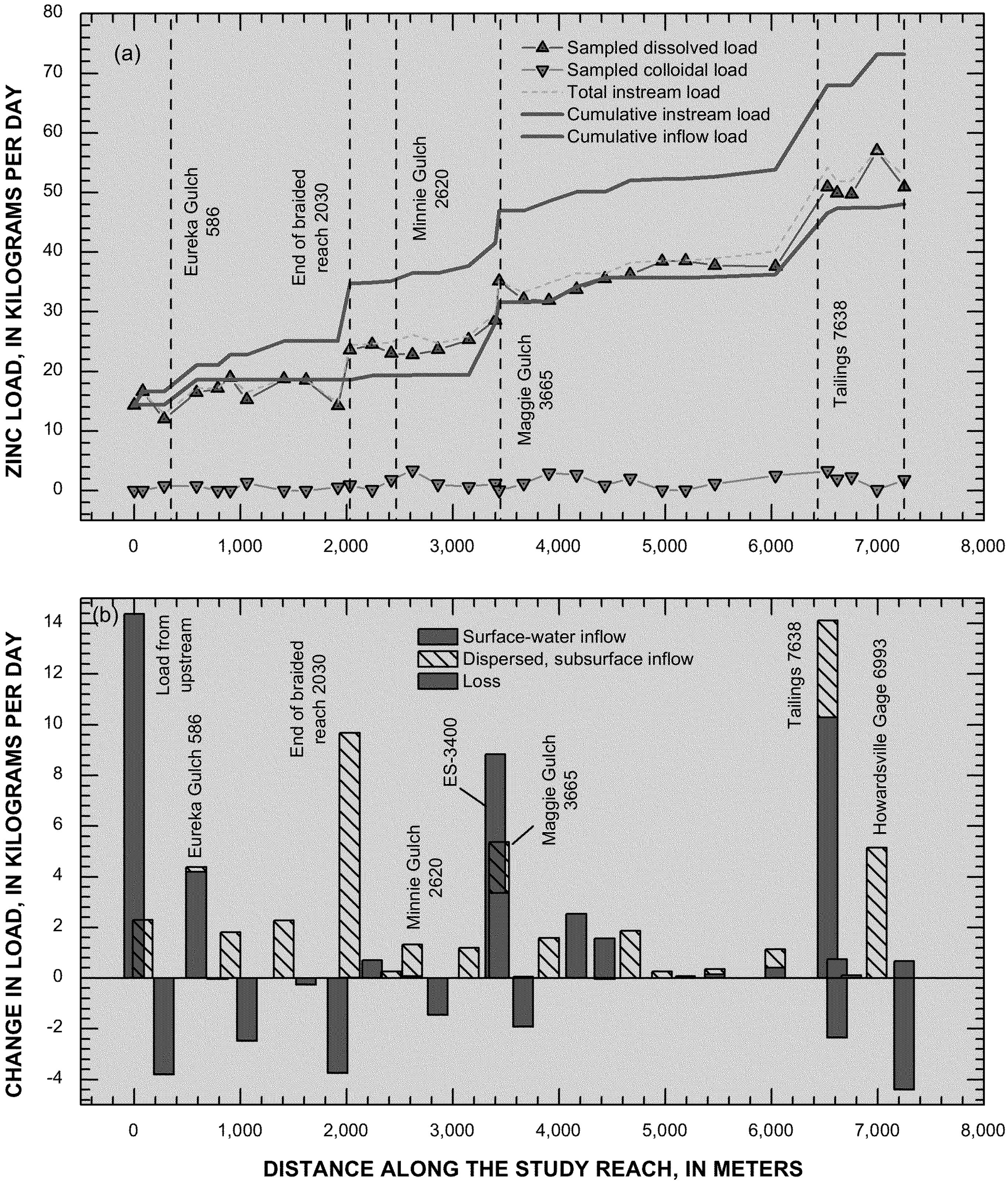

Figure 73. Variation of (a) zinc load with distance along the study reach and (b) change in load for individual stream segments.

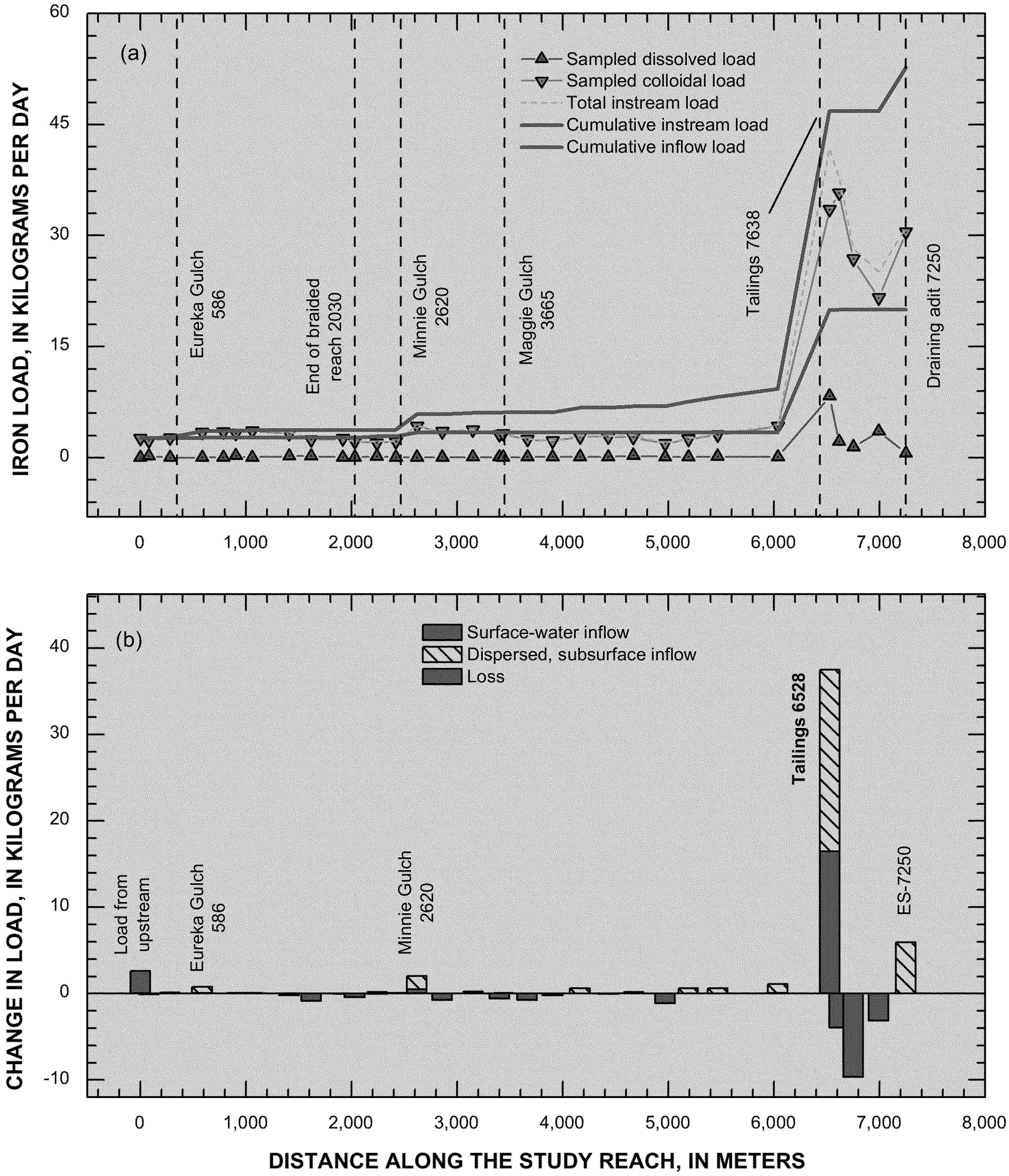

Figure 74. Variation of (a) iron load with distance along the study reach and (b) change in load for individual stream segments.

The third pattern of metal loading is represented by strontium (fig. 75) and sulfate (fig. 76). For both these solutes, there were many more sources of loading along the study reach than for the other solutes because their sources were not limited to the ore minerals. For example, Cunningham Gulch (ES-6618) was a major source of loading only for strontium and sulfate, but the tailings drainage near Howardsville (ES-6528) was a relatively minor source (figs 75b and 76b). Another difference for these two solutes is that the majority of the load was surface-water inflow, and not subsurface inflow (table 24). There was some loading by subsurface inflows for sulfate, however, at ES-4670 and ES-4970.

Figures 75 and 76 near here.

Principal sources of metal load

There were three locations where most of the metal loading occurred along the Eureka to Howardsville study reach (table 25). For aluminum, copper, zinc, and sulfate the greatest loading was from sources upstream from the study reach, although for copper this load is indicated in the segment at ES-80. Upstream sources were also important for manganese, but the greatest source of iron and manganese was the segment draining the old tailings near Howardsville (ES-6528). This segment also was important for aluminum and zinc. Finally, the last two segments along the study reach, ES-6993 and ES-7250, were important sources of cadmium, copper, iron and zinc. There were more segments that with at least 5 percent of the load for strontium and sulfate than for the other solutes. This pattern is consistent with multiple sources for these two solutes that are more widespread throughout the watershed, and not just confined to those segments most associated with mine drainage.

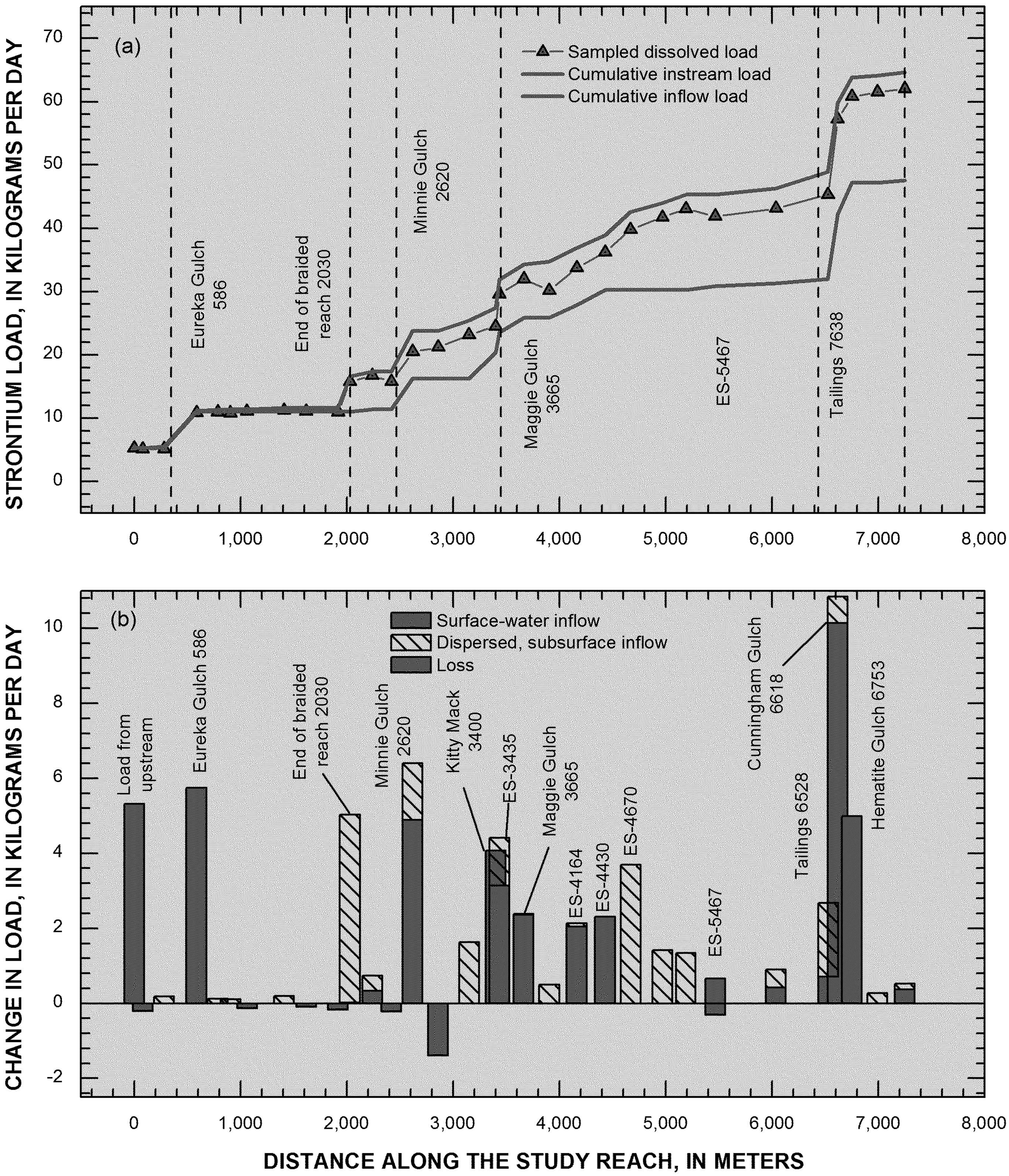

Figure 75. Variation of (a) strontium load with distance along the study reach and (b) change in load for individual stream segments.

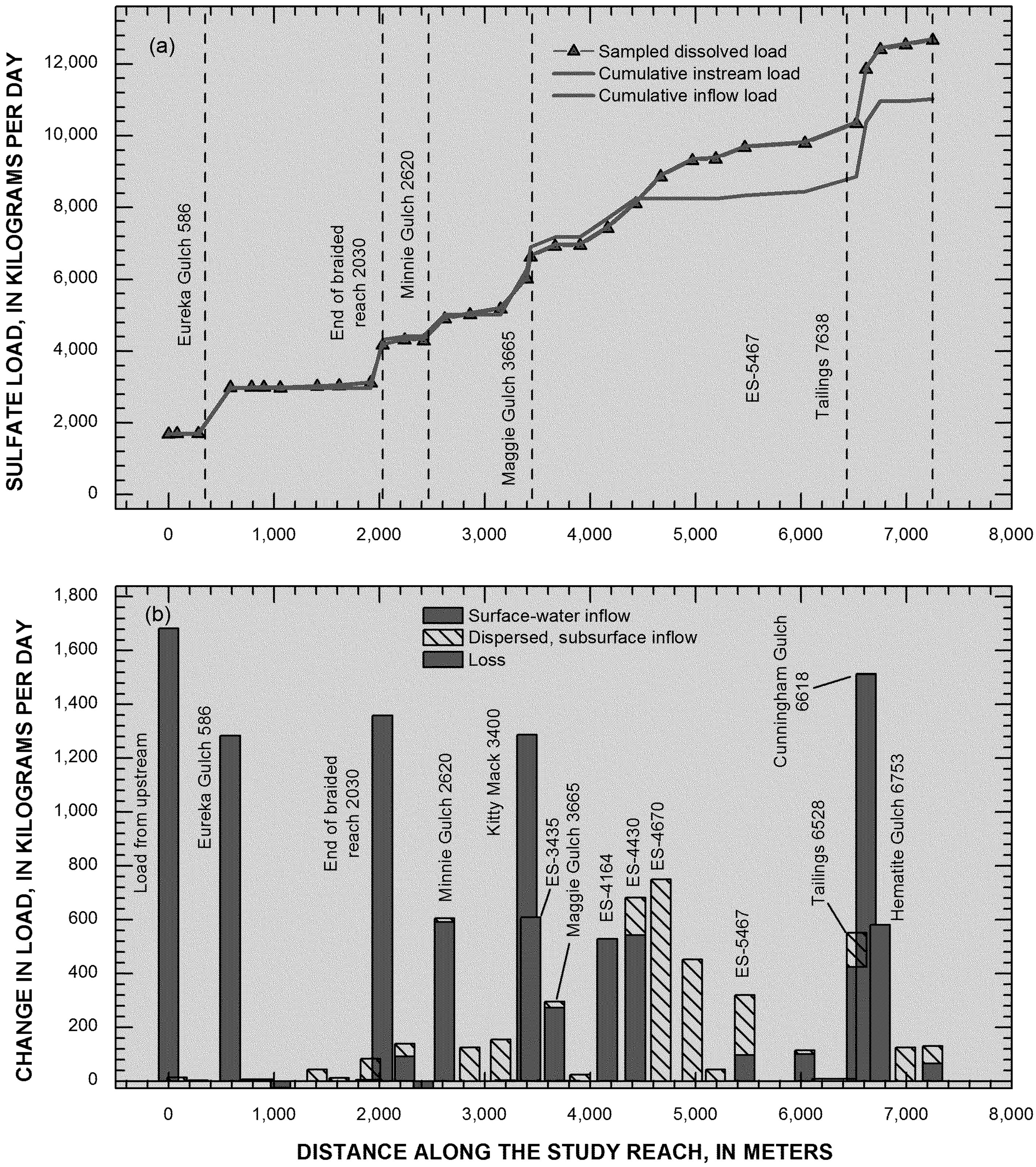

Figure 76. Variation of (a) sulfate load with distance along the study reach and (b) change in load for individual stream segments.

Table 26. Locations of major loading to upper Animas River, Eureka to Howardsville, Colorado, August 1998.

[Distance, in meters along the study reach; all other values in percent of cumulative instream load; value with bold print are greater than 5 percent of the total; Al, aluminum; Cd, cadmium; Cu, copper; Fe, iron; Mn, manganese; Sr, strontium; Zn, zinc; SO_4, sulfate]]

Site identifier	Distance	Al	Cd	Cu	Fe	Mn	Sr	Zn	SO_4
ES-0	0	**32.3**	**7.9**	**9.5**	**5.0**	**36**	**8.2**	**20**	**13**
ES-80	80	-0.2	3.4	**24**	-0.2	-1.0	-0.3	3.1	0.1
ES-586	586	**5.5**	3.7	-.9	1.5	3.1	**8.8**	**6.0**	**10**
ES-1411	1411	-1.5	-4.5	**13**	-.3	.6	.3	3.1	.4
ES-1618	1618	-2.9	**5.5**	4.0	-1.6	0.0	-0.1	-0.4	0.1
ES-2030	2030	1.8	4.0	1.4	-0.8	1.8	**7.8**	**13**	**8.3**
ES-2620	2620	**10**	3.3	-.2	3.9	3.2	**9.9**	1.8	4.8
ES-3400	3400	-4.9	**13**	1.8	-1.1	-2.0	3.2	**5.3**	**6.6**
ES-3435	3435	.6	-5.5	-.7	.2	-0.4	**6.8**	**7.3**	4.8
ES-3905	3905	3.4	**7.9**	.2`	-0.4	.4	.8	2.2	.2
ES-4430	4430	3.3	.2	.3	-0.1	-2.3	3.1	-0.1	**5.4**
ES-4670	4670	-2.2	-5.2	-1.8	.4	-0.8	**5.7**	2.6	**5.9**
ES-5467	5467	**12**	**11**	**5.3**	1.2	-1.7	-0.5	0.5	2.5
ES-6038	6038	-4.0	**7.1**	-4.9	2.1	0.0	1.4	1.6	0.9
ES-6528	6528	**15**	-8.0	-1.8	**71**	**50**	4.1	**19**	4.4
ES-6618	6618	-7.7	-3.3	3.1	-7.4	-4.2	**17**	-3.2	**12**
ES-6753	6753	**8.5**	2.8	**8.7**	-18	1.9	**6.3**	0.1	4.3
ES-6993	6993	-2.4	**14**	**11**	-6.0	-0.5	.4	**7.0**	1.0
ES-7250	7250	-0.3	3.6	-20	**11**	1.0	.8	-6.0	1.0

Dispersed, Subsurface inflows

Subsurface inflow, which was calculated as unsampled inflow, was responsible for over half the loading for aluminum, cadmium, copper, and iron (table 24). Subsurface inflow was less important for manganese strontium, zinc and sulfate, but did occur for each solute. There were two main locations of subsurface inflow. The segment draining old tailings near Howardsville (ES-6528) was important for aluminum (fig. 70b), iron (fig. 74b), and manganese (fig. 72b). The segment at the end of the braided reach (ES-2030) was important for strontium (fig. 75b) and zinc (fig. 73b). Segments ES-470 and ES-4970 were important for the inflow of sulfate (fig. 76b) and, to a lesser extent, strontium (fig. 75b).

Attenuation

Over half of the copper, cadmium, and aluminum loads were removed along the study reach (table 24). As noted for copper and aluminum, much of this attenuation was in the upper part of the study reach, in the braided reach. There was very little attenuation of strontium and sulfate. About 25 percent of the manganese and zinc loads were removed. The 41 percent attenuation for the iron load most likely was an underestimate because only a net reaction was measured for each segment by the tracer study.